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FERMILAB-Proposal-0727

November 2, 1982

Dr. Leon Lederman
Director
Fermi National Accelerator Laboratory
P.O. Box 500
Batavia, Il. 60510

Dear Leon:

The Northwestern group would like to participate in the DO Workshop November 19, 20, and make a presentation. We believe that we have a number of attractive and compelling ideas to discuss.

The Tevatron collider opens up a rich regime of new physics. Much of this will be explored by the C.D.F. Nevertheless, certain design decisions have been incorporated into the C.D.F., the primary thrust of which has been to optimize large angle detection. It is natural therefore to contemplate a second detector geometry which is somewhat orthogonal to that of the C.D.F. and gives highest priority to forward particle detection. It is well to remember that 90° in the C.M. of either of the colliding hadrons corresponds to a laboratory angle of 45 milliradians. The second spectrometer geometry should key on the angular range (15-200) milliradians.

The Northwestern group is particularly interested in the development of forward direction electromagnetic shower detectors. We have gathered considerable experience with such physical detectors from work with the liquid argon detector that we successfully built and operated for E-515. We have new ideas for improving and refining the capabilities of a finely sectorized shower detector. They dovetail nicely with both the DO space limitations and the pulsed beam operation.

Our physics interests encompass the full range of possibilities inherent to shower detection plus magnetic tracking.

1. Inclusive $e^{\pm}$, $\mu^{\pm}$, ${}^{e}m$, correlations etc. Heavy quark and lepton semileptonic decay, W decay.

2. Low and high mass lepton pair production at medium and large x continuum, $c\bar{c}$, $b\bar{b}$, $t\bar{t}$(?) Z^{0}(?).

3. Prompt photon production - γ, π°, η, separation, K°_{s}, ω° detection.

4. Jet physics.

We have been lead to consider the type of spectrometer geometry in which our proposed shower detector could be incorporated. We hope to convince you, your advisors and potential collaborators that the most flexible and economic geometry, is one built around a particular form of split field magnet. Such an "open geometry" facilitates a rather flexible arrangement of detector systems as opposed to one based on a mammoth solenoidal detector. The participating collaboration can be a bit looser and more fluid. While most of the 4π solid angle can be "squeezed" for physics (the region shadowed by pole forces could feature iron based calorimetry),

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solid angle can be partitioned out with less conflict. For example, a sector could be reserved for Cerenkov detection or it could be replaced by shower detection. We hope to make all of this clearer at the workshop.

Please do not interpret any of the above remarks as criticims of the C.D.F. It is a most impressively conceived and organized activity. We simply propose to complement its capabilities. So far as we can see the solenoid plus end cap systems have used up most of the axial length available (between the low β quads) and it may prove to be extremely awkward to install forward bending magnets with adequate space for tracking. In any case, the first round of activity calls for muon toroids, calorimetry etc., and does not feature magnetic tracking of charged particles that will be intercepted by the forward shower detectors. Surely, this forward regime of physics deserves top priority in a second area.

We very much look forward to frank and thoughtful exchanges at the DO Workshop.

Sincerely yours,

J. Rosen

Jerry Rosen
Professor of Physics

JR/kmv

Do Spectrometer Design Proposal

The Northwestern High Energy Physics Group

Spokesman: J. Rosen

Introduction

The purpose of this proposal is to offer two specific contributions.

1. The overall D_o detector design architecture. We will outline the reasoning which underlies the particular geometry we have chosen and consider it to be the one which best exploits the opportunity afforded by D_o. We believe that it is presumptive to attempt to provide serious designs for all of the major subsystems of the spectrometer. We anticipate a merging of several collaborations and parties who have interest in D_o once the optimum overall design architecture is selected by Fermilab. The detailed subsystem design can only proceed when more specific goals, time schedules, space limitations and overall cost constraints are established.

2. One very specific subsystem which we propose to construct is a pair of E.M. shower detectors to operate in the forward regions (1^o-15^o). We have a number of solid and innovative ideas to put forth. We have construction, operation and analysis experience obtained in the M1 beam line to draw upon. The scope of the proposed commitment is reasonably well matched to our Northwestern resources.

Spectrometer Design

The advent of TEV I will provide a CM energy of 2 TeV ∿45 times greater than that available in the fixed target program and ∿3 times greater than the SPS Colliding System. With three circulating $\bar{p}$ bunches we can look forward to an interaction rate ∿few x10^4/sec. This is approximately one order of magnitude below the interaction rates which have been sustained in those fixed target experiments featuring large aperature spectrometers. Such a valuable resource deserves full utilization - 4π detection. In fact, the totality is of greater value than the sum of the constituent systems - dynamical constraints (e.g. $p_\perp$ balance) accrue.

We defer for the present a discussion of physics goals and motivations. The task of designing a 4π detector geometry is more akin to that presented by a bubble chamber complex than to that normally encountered in fixed target physics.

For the purpose of our discussion we distinguish 3 regions of acceptance (polar angle defined) the beam hole region (0-1°), the forward region (1-15°), the central region (15-90°).

(0-1°)

Most of the reaction energy flow goes down the pipe. Several proposals discuss this region in detail. A relatively modest goal is to squeeze the uncertainty in missing $p_\perp$ to the barest minimum. A more ambitious goal is to measure the longitudinal energy flow to sufficient accuracy as to facilitate a useful constraint on the amount of energy that is released in the central collision process. In considering such a prospect there are a number of grave concerns. Some form of staggered calorimetry must by employed and one must evaluate energy losses in cracks. Forward neutrino losses are a second concern. Compatibility with beam elements including low β quadrapoles, are also to be considered. Presumably, one will be loathe to sacrifice luminosity particularly in the early stages of operation. Some real hard performance data obtained from simulation tests carried out with a low flux proton beam and a fixed target would be useful if not imperative, before commiting to luminosity sacrifice.

In any event, none of the ideas we are presenting in this proposal preclude the execution of beam line energy detection to the ultimately achievable sensitivity. We do not vie for that responsibility.

At this juncture, before considering the ($1-15^{o}$) and ($15-90^{o}$) regions we must make a decision - magnetic tracking around the collision region vs. nonmagnetic spectrometer. In the absence of a central magnetic detector, one proceeds with EM shower detectors and calorimetry plus muon detection. The obvious advantages of this choice are: It is more compact and cheaper, magnet power consumption is avoided and the decay path for the production of uninteresting leptons from π,K,Λ ... decay is reduced to the barest minimum.

The advantages of magnetic tracking are: Momentum tracking is inherently of higher resolution than calorimetry. Of course calorimetry is essential for neutrals - n, $\bar{n}$, k^{o},π^{o} excluded It is one thing to require calorimetric information for (10-20)% of the total energy flow, it is far cruder to be totally dependent on it. Charge sign is identified. This is particularly valuable for $e^{\pm}$. One can study same sign, opposite sign correlations and other correlations such as charge vs rapidity (e.g. $W^{\pm}$ production is expected to correlate with p($\bar{p}$) direction). Electron-hadron separation is ∿10 times improved with momentum information available.

The advantages of the nonmagnetic system are less than dramatic if one considers the situation further. It is not really prudent to collapse the detector system to the "iron ball" limit. The segmentation of the EM shower system and the inner hadronic calorimetry layers, the quality of energy flow direction determination, overlap problems etc. strongly suggest leaving some void surrounding the beam pipe in the collision region. Furthermore, some kind of inner tracking system is advisable in order to pin down the event vertex and locate an accidental vertex if any.

The mean transverse radius of the calorimetric iron is

$\approx$ Void radius (or magnetic tracking radius)
+0.5m (for shower detection)
+1m (assuming Calorimeter Fe ~ 1.5m thick)

The cost presumably scales as the cube of this quantity. A void radius would be $\lesssim$ 0.5m while a "reasonable" magnetic tracking system could be provided within 1m radius.

Conclusion: A 4π detector requires $>10^3$ ton's of Fe; therefore we might as well provide it with coils and develop an interior magnetic field.

Having opted for a magnetic field, we believe that it would be exceedingly unwise to choose a longitudinal field. The D_o area would replicate the C.D.F. A transverse field provides a complementary choice. See figure 1 for a comparison of the longitudinal and transverse options.

Figure 2 illustrates an extremely large (and appropriate) window frame dipole magnet. Such a magnet will cost several millions of dollars. The field is vertical in deference to the minibypass system. The minibypass deflects the main ring beam pipe to a distance of 2 meters above the Tevatron beam. In the position shown, the main ring passes through regions of calorimetry i.e., coarse detector systems which are not severely compromised by the intrusion. The dipole field in this region should be relatively weak. A portion of the Fe yoke-calorimeter surrounding the beam pipe will be replaced with a non magnetic matrix of Al and Pb so as to provide a non magnetic enviroment. It should not prove to be excessivly difficult to reduce the residual field in the pipe to the level of a hundred gauss.

The UA1 magnet system which is of comparable size has a field direction parallel to the ground. This makes possible access to the detector interior by a relatively simple horizontal split of the two symmetric detector halves. The vertical field we have chosen in deference to the minibypass does not permit this. The coils cannot be split. We propose to make the upper pole face modular and in sections which can be handled by a crane. The saddle coil construction gives access thru the magnet ends. The UA1 system does not employ saddle coils. It may be argued that the construction of properly vacuum impregnated saddle coils of this size is prohibitively painful. We have some thoughts to be described later on which may ameliorate the pain.

We opt for Cu coils and a power ~2 MW. We anticipate that the magnet will be fully powered with a 25% duty factor. The Cu is perfectly good (if expensive) calorimetric material.

The window frame magnet has four attractive features

1. Accessibility at the ends.

2. The forward detection regime (1-15°) will be carried outside the magnet. The magnetic field deflection will be tracked over a large distance (5m) and the shower detector segmentation will be more effective.

3. If nature should surprise us with some new long lived charged particle we will have a large window to study it with.

4. The ambient flux of low energy radiation in the magnet cavity should be reduced. This should be beneficial to the central tracking system.

Figure 3 shows schematically the disposition of the major detector systems.

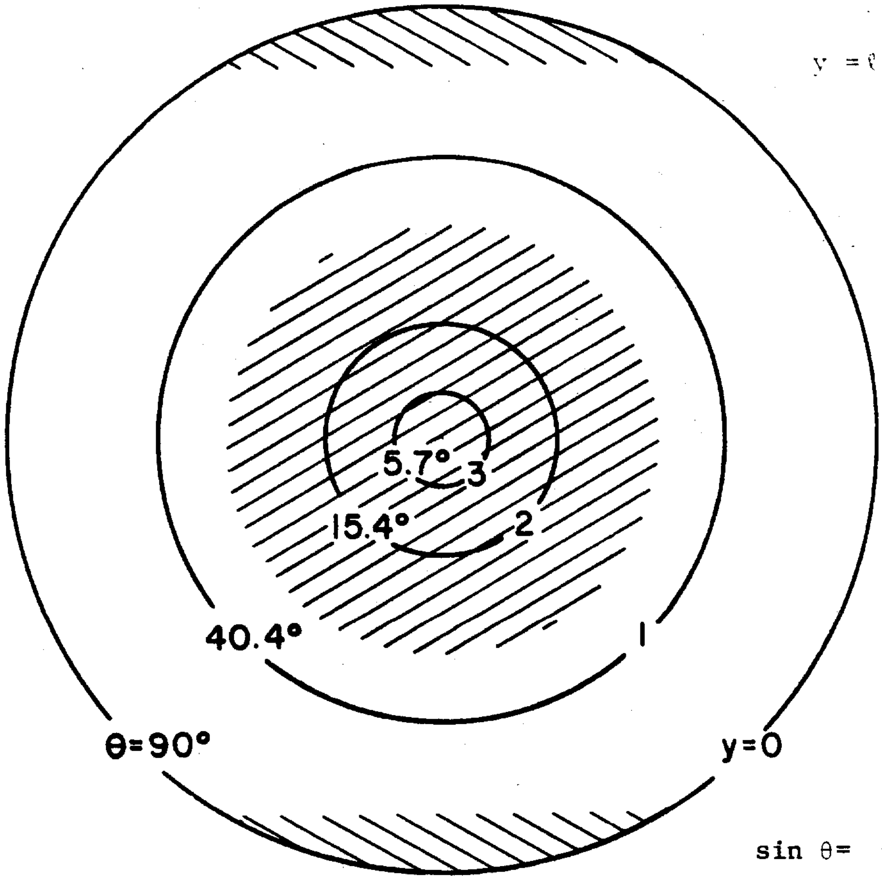
1,2,3 - Drift chamber tracking chambers.

4,5 - Internal EM Shower detectors.

6 - Forward shower detectors.

7,8,9 - Fe based calorimetry.

$y = \ell n(\cot\frac{\theta}{2})$



$\sin\theta = \frac{2}{e^{y}+e^{-y}}$

for small θ, $\theta \approx 2e^{-y}$

Figure 1. Hemisphere projection of the polar angle plot. Zero degrees corresponds to the beam pipe direction. Circles of constant pseudorapidity (y) are indicated. The half width at half maximum of the central rapidity plateau is predicted to correspond to $y \approx 5$ for TEV I. This is for general inclusive production. For $W^{\pm}$ production the half width at half maximum is $y \approx 2$. The central shaded region indicates the end cap regime of the C.D.F. ($\theta < 30^0$) where the magnetic tracking is very weak or nonexistant. The oppositely cross hatched areas correspond to the analogously weak tracking regions for a transverse field spectrometer such as UA1.

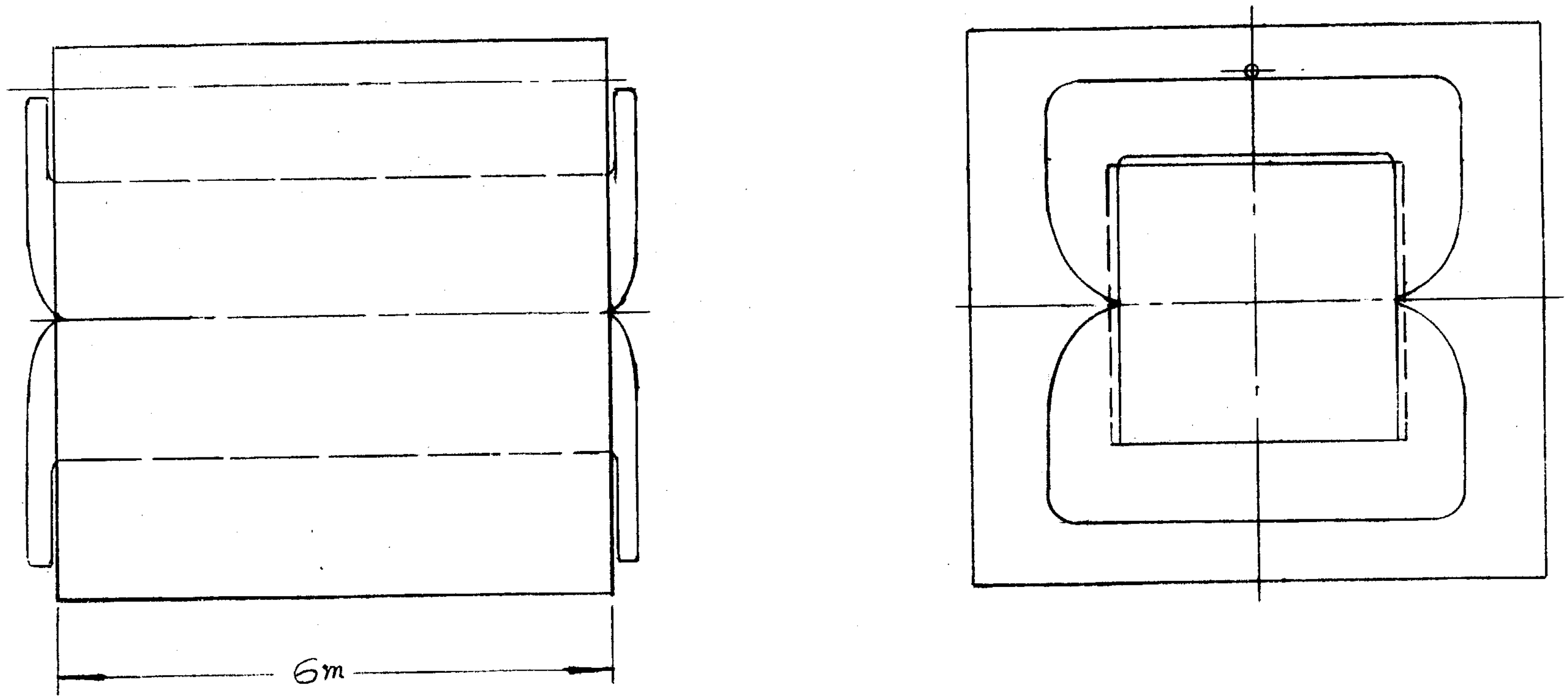


Figure 2

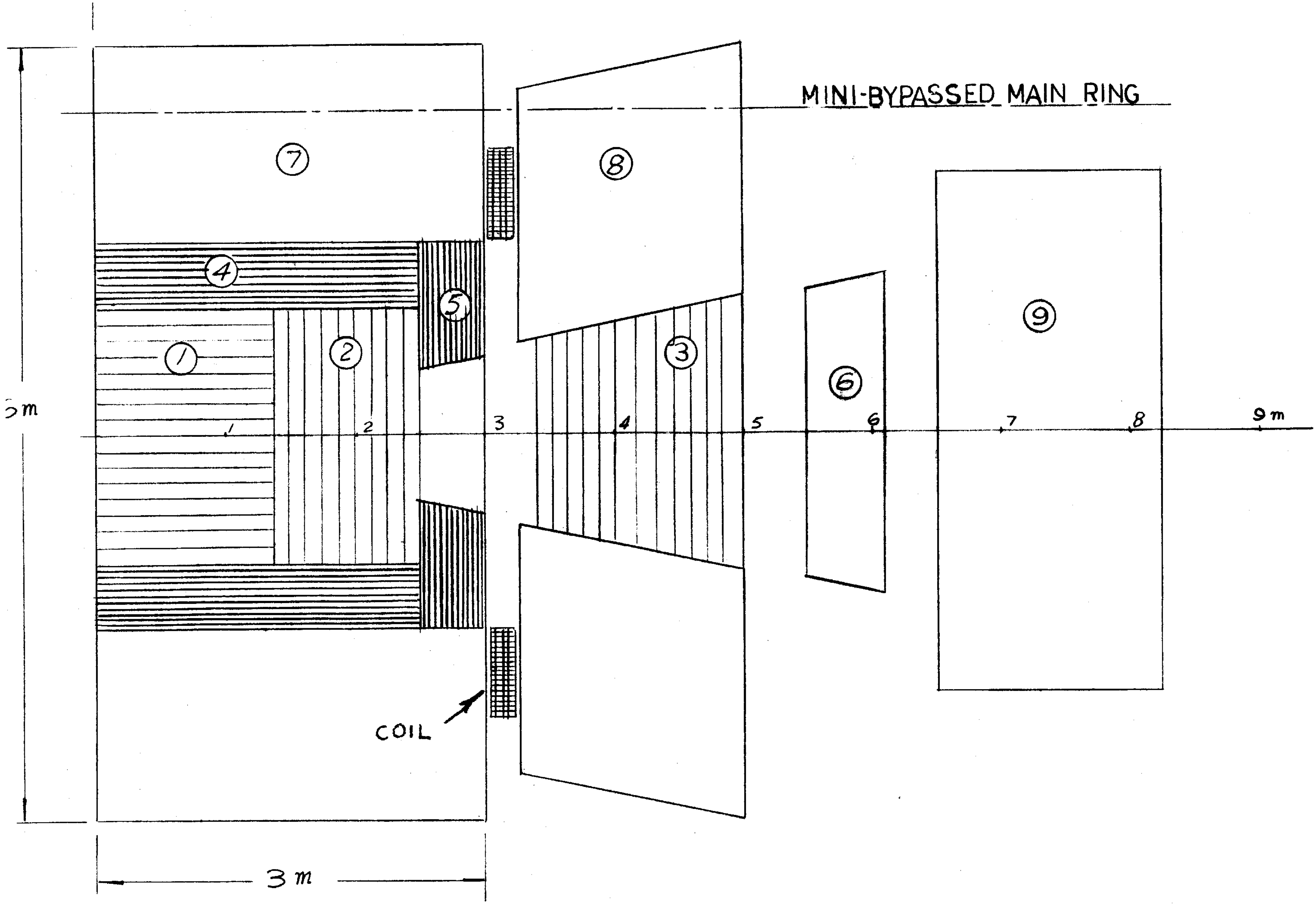


Figure 3